DETERMINATIONS OF ATMOSPHERIC TURBIDITY AND WATER VAPOR CONTENT

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Introduction.—Early in 1931, at a meeting of the commission on solar radiation of the section of meteorology, International Geodetic and Geophysical Union, in Potsdam and Berlin, Germany, after a thorough discussion it was voted to recommend to the national branches of the Union that they cooperate in a world-wide study of the dustiness or turbidity of the atmosphere, and also of the water vapor content.

The commission recommended that glass color filters be utilized to separate out from the complete solar spectrum the bands that were free from water vapor absorption; and the Magnetic-Meteorological Observatory at Potsdam was asked to procure glasses of suitable quality and of uniform thickness and spectral transmission, and to test them for quality and uniformity throughout.

With characteristic thoroughness, the observatory secured a considerable quantity of OG1 (yellow) and RG2 (red) Schott filter glass. From large sheets, disks of suitable size were cut, ground to uniform thickness, and their spectral transmissions carefully determined. The results of these tests were published by Feussner, Met. Zeit. 1932, Heft 6, S.242–244; they have been reproduced in this REVIEW, March 1933, volume 61, pages 80–82.

Early in 1932 a set of these filter glasses was received at the United States Weather Bureau; and later in the same year a second set was received at the Blue Hill Meteorological Observatory of Harvard University.

Check readings made by the United States Bureau of Standards on both sets of these screens gave results in close accord with the Potsdam tests. During the following winter these tests were repeated at the Bureau of Standards, and also at the Smithsonian Institution; these tests made in cold weather gave slightly higher transmissions than did the earlier tests made in midsummer heat. Feussner states that the temperature of the screens when undergoing test in his laboratory was between 20° and 25° C.; it is here assumed that the mean of the temperature during his tests was 22.22° C., which corresponds with 72° on the Fahrenheit scale.

The effect of temperature on the transmission of glass filters receives more complete treatment later in the present paper.

In the United States, the United States Weather Bureau and the Blue Hill Observatory of Harvard University have made solar radiation records with these filters since 1933. All measurements have been utilized in obtaining values of the turbidity coefficient, β, and of the water vapor content, w, of the atmosphere. While the first measurements did not yield as accurate results as

could have been wished, they indicated defects that have been remedied and which could not have been discovered except through experience.

In middle and northern Europe, a very complete system of observing stations was early established. The locations of some of the mountain stations are excellent, and from some use the writer has made of them for other purposes they are judged to hold much promise for the calculation of atmospheric turbidities and water-vapor contents over a wide range of territory. It is hoped this material does not long remain unavailable; so far as can be learned, neither the Weather Bureau library nor the library of the Blue Hill Meteorological Observatory has yet received any values of β or w derived from the measurements made at the European stations.

A considerable literature on the subject of this paper already exists, references to a part of which will be found at the end of the paper. A complete bibliography does not seem to be required here, because the specific purpose for which this paper has been written is to place on record the technique that has been developed at Blue Hill, largely under grants from the Milton fund of Harvard University, for determining the atmospheric tubidity and water vapor content.

The technique which was first developed and published by Ångström (1), is here considerably modified, especially with reference to the effect of the temperature of Schott glass filters upon their transmission of solar radiation.

Ångström's atmospheric turbidity coefficient, β, is preferred to Linke's (2) coefficient, T, for the reason that Linke includes in this one term, T, all depletion of the solar rays as they pass through the atmosphere to the place of observation; while Ångström separates depletion due to scattering from that due to absorption, and thus makes possible a close approximation to the water vapor content of the atmosphere above the place of observation.

Pyrheliometric apparatus and its exposure at Blue Hill.— On the monument which stands beside the path leading to the observatory, and which was erected to the memory of the founder, Professor Rotch, it is stated that he was a "Pioneer in the study of the upper air" (fig. 1). At that time this study was made by means of delicate instruments that were taken to considerable heights by kites or balloons. Now we learn much about the upper atmosphere from its effects on the solar rays as they pass through it on their way to the surface of the earth. Therefore, the present director, C. F. Brooks, was only expanding the program of the founder when he added measurements of the intensity of incoming solar radiation to the daily routine of the observatory.

In figure 1, just to the left of the monument, is a glimpse of the top of the observatory tower. Just past the crest of the hill, the observatory is seen as it appears in figure 2; in the side of the tower shown, which is the north side, are three windows, one above another, and the central one has in it an instrument shelter of a style in common use at the time the observatory was built. A modern shelter is now located on the ground, farther to the northeast.

This picture was taken during the celebration of the fiftieth anniversary of the founding of the observatory. In the pathway, from left to right, are President Conant; Charles Francis Adams, chairman, executive committee of the board of overseers, Harvard University; W. S. Gifford, and M. Simons, members of the board of visitors, Blue Hill Meteorological Observatory.

Figure 3 is a closer view of the tower. Note the openings in the parapet. There are eight of these openings: The one nearly in front is the easternmost. The second one to the left is in the south side of the parapet and in front of this opening a concrete pier has been built up to the height of the bottom of the opening. At its base the thickness of the pier from north to south is considerably greater than at the top, and its width from east to west exceeds throughout its thickness from north to south. One of the leveling screws, or pins, of the equatorial mounting for the Eppley thermopile rests on the bottom of the south opening in the parapet, while two others rest on the pier. This makes a support for the equatorial and the thermopile it carries, which is as stable as the tower itself.

By means of the three leveling screws, the support is easily adjusted to the vertical, and a pair of screws enable the instrument to be accurately pointed toward an object near the horizon several miles away that is shown by geodetic-survey maps to be only a very small known angle from due south of the observatory tower. With the thermopile tube properly mounted on this support, and adjusted each day for solar declination and each morning for solar hour-angle, it is a simple matter to correct the setting before obtaining each series of solar-intensity records on the Leeds and Northrup micromax recorder.

Figure 4 shows the thermopile tube, mounted on the equatorial, in operation. Over the upper end of the tube is a quartz plate, one-half millimeter thick, that protects the thermopile from disturbance by the wind. Above the end of the tube is a Schott glass color filter; two of these filters are mounted on opposite sides of a spindle that is turned by hand to bring the desired filter over the end of the tube or to remove both of them.

Beyond the parapet and apparatus in figure 4, is a glimpse of the valley to the southwest of Great Blue Hill. The terrain beyond the east slope of the range, as shown in figure 4, consists principally of forested areas, scattered lakes, and cultivated fields. The western slope is more gentle than the eastern, and in the earlier days of the observatory a carriage road was built up this slope; it may still be used by horse-drawn vehicles, but is closed to automobiles. The Blue Hill Range ends very abruptly just beyond the observatory, so that from the south and west the observatory has the appearance of occupying an isolated peak. To the north, the center of Boston is about 11 miles distant; and in the morning the horizon in that direction is usually obscured by smoke, which often lifts in the afternoon. Through the valley to the west is a line of suburban towns served by the New York, New Haven & Hartford Railroad; but the smoke from the trains is so well controlled that this valley is usually quite free from smoke. The density of the smoke or haze prevailing at the time screened readings are obtained is indicated on a scale of 10 units which give the distinctness and distance to which large objects can be seen. Mount Monadnock, at a distance of about 67 miles, in New Hampshire, with an elevation of 3,166 feet, and Mount Wachusett, elevation of summit 2,096 feet and distance from the observatory 44 miles, are visible only when the visibility is rated 9 or 10.

There are a number of hills and other objects that help fix the degree of visibility, or measure the transparency of the atmosphere. The results are tabulated and published monthly as an auxiliary to table 3, Solar Radiation Observations, in this REVIEW.

Since Blue Hill is in a metropolitan forest reserve area, and since there are also other forest reserves in the vicinity, the present favorable atmospheric conditions for solar radiation work may be expected to continue and possibly improve.

The measurement of solar radiation intensity.—In figure 5 is reproduced, on about half its original scale, the continuous record obtained at the Blue Hill Meteorological Observatory on December 28, 1935. The original records are made by an Eppley thermopile supported on an equatorial mounting as shown in figure 4, and carefully adjusted as explained above. The accuracy with which the thermopile tube is pointed on the sun is tested, and the setting corrected if necessary, before each set of screened readings. The thermopile actuates a Leeds and Northrup recording micromax potentiometer which is hung on the heavy concrete wall of a room on the first floor of the tower, and with which it is in electrical contact through well insulated copper leads. Before it was issued by the Eppley Laboratory, the 10-junction thermopile was carefully calibrated on a Leeds and Northrup micromax recording potentiometer, similar in every respect to the one in use at the Blue Hill observatory. The calibration showed that one division on the record sheet indicated a radiation intensity of 0.05 gram cal./min./cm^2 of surface.

On each clear day the Smithsonian silver disk pyrheliometer, which is preserved as a standard of reference at the observatory, is read; its reading is corrected for the temperature of the bulb and the temperature of the stem, a calibration correction applied for that part of the stem at which the reading was made, and the corrected reading multiplied by the constant for this particular instrument, which is 0.3827. This shows that the thermometer in this pyrheliometer is a sensitive one.

In table 1, which follows, are given the ratios, Smithsonian to Eppley, the latter values recorded as they were read from the record sheet for the time at which the Smithsonian pyrheliometer was read. It will be noted that these ratios vary from day to day, and to a less extent from hour to hour, and that in general the clearer the sky the higher is the ratio. The variation from low sun to high sun may be explained by the fact that the sky is relatively brighter about the sun when the sun is low than when it is high in the heavens. It is known that pyrheliometers, and other similar instruments for measuring solar radiation intensity, include in the measurement the radiation from a small ring of the sky surrounding the sun. To eliminate this as far as possible, the Smithsonian Institution uses a vestibule in front of the blackened absorbing surface, of such length as to require special means for supporting and handling it (3).

Probably the variations in the ratios of table 1 are due to the slightly larger percentage area of skylight to which the Eppley thermopile is exposed as compared to
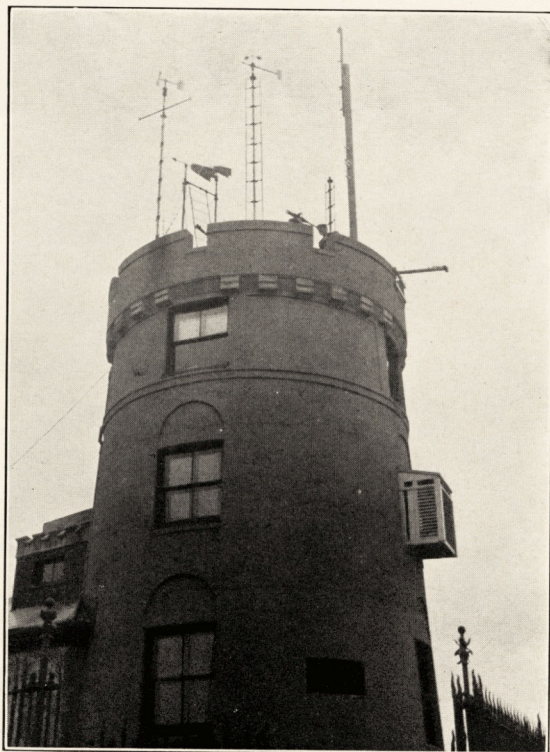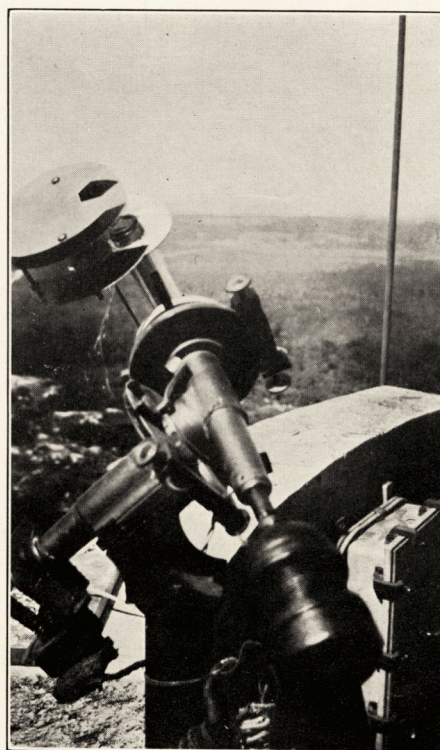
FIGURE 1.

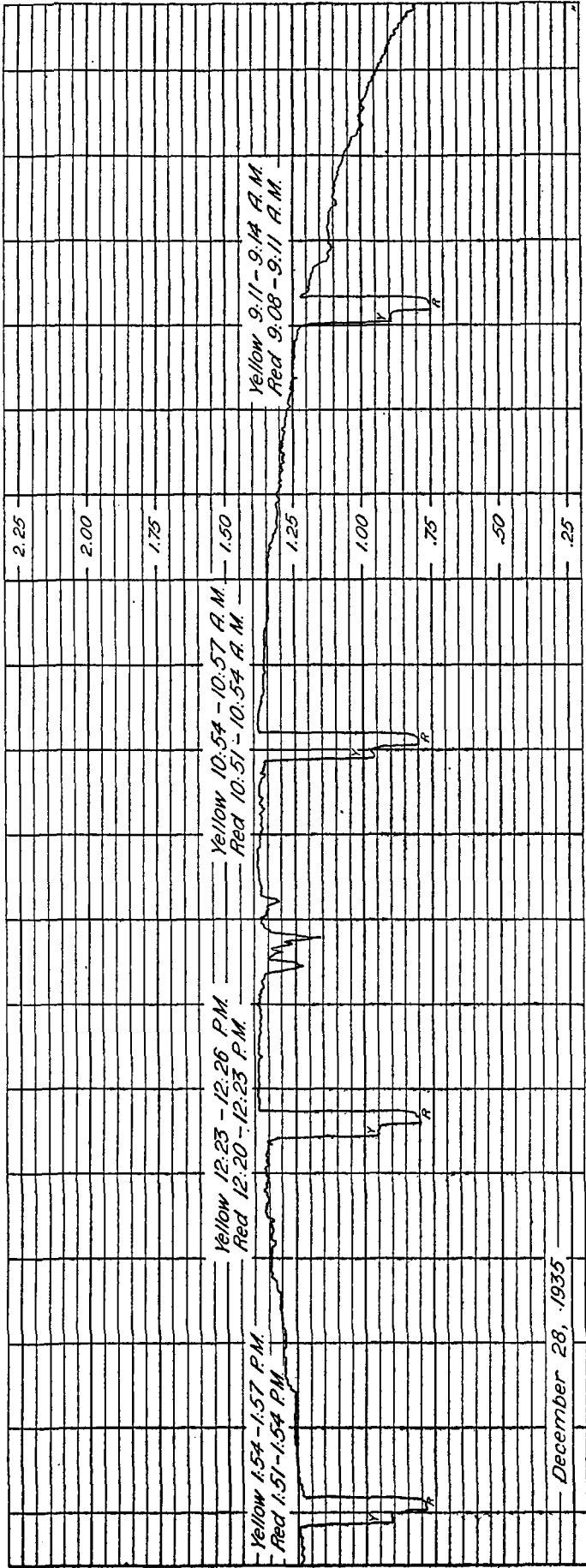

FIGURE 2.

FIGURE 3.

FIGURE 4.

Figure 5

that from which the Smithsonian pyrheliometer receives radiation, since the clearer the sky, the larger the ratio Smithsonian (gr. cal.)/Eppley (scale). The discrepancy would be eliminated if the two instruments had vestibules that offered the same angular opening from their respective blackened surfaces to the sky; in the meantime, the ratios from table 1 for each day must be employed in reducing scale readings from figure 5 to radiation intensities expressed in heat units, else the turbidity values computed by the method to be explained would show discrepancies.

TABLE 1.—*Ratio of Smithsonian pyrheliometer readings to scale readings of the Eppley thermopile recording on Leeds and Northup micromax automatic register*

1935	Time	Smithsonian pyrheliometer gr. cal./min./ square cm.	Eppley thermopile: Scale readings	Ratio: Smithsonian/Leeds and Northup scale reading
Dec. 3	9:08 a. m	1.028	2.23	0.461
Dec. 4	1:32 p. m	1.244	2.55	.488
Dec. 6	9:42 a. m	1.290	2.79	.462
Dec. 12	8:50 a. m	.959	1.92	.499
Dec. 17	3:48 p. m	.431		
Dec. 18	8:56 a. m	.956	2.05	.466
Dec. 21	8:46 a. m	.951	1.98	.480
Do	11:30 a. m	1.274	2.59	.492
Dec. 22	8:54 a. m	1.172	2.38	.492
Do	11:30 a. m	1.380	2.84	.486
Do	12 noon	1.386	2.85	.486
Dec. 23	10:10 a. m	1.151	2.37	.486
Dec. 25	11:16 a. m	1.357	2.74	.495
Dec. 27	11:28 a. m	1.313	2.64	.497
Dec. 28	12:10 p. m	1.395	2.77	.503
Dec. 31	12:14 p. m	1.418	2.82	.503

Note that the ratios in the last column of this table are, on an average, in good agreement with Eppley's calibration value.

To illustrate the method of computing β and w, there are tabulated in full in table 2 the radiation data for December 28 obtained from figure 5 by the use of the ratios for the same date in table 1. Note that the time entered on figure 5 for each series of measurements is standard seventy-fifth meridian time, on which all Blue Hill observatory recording instruments are run. In table 2, the time is reduced to true solar, or apparent time, but is entered as hours and minutes before or after apparent noon, for convenience in computing the solar altitude and the air mass or relative length of path of the solar rays in the atmosphere; unit air mass is the length of path when the sun is in the zenith and the barometric pressure is 760 millimeters. By interpolation in Ball's Altitude and Azimuth tables (4), the altitude of the sun has been tabulated for the latitude of Blue Hill observatory for each degree of solar declination from +24° to −24°, and at 4-minute intervals from shortly after sunrise to within a few minutes of sunset. From the sun's altitude, the corresponding air mass may be obtained from table 100, page 226, Smithsonian Meteorological Tables, Fifth Revised Edition, 1931, or other sources. These air mass values are computed for an air pressure of 760 millimeters; and at Blue Hill, because of the elevation, the values derived in this way must be reduced by multiplying by 0.98.

In table 2, following the air mass are the measured solar radiation intensities designated in the column headings I_m, I_y, and I_r; these are respectively intensities for the total solar spectrum, for that part of the spectrum transmitted by the yellow filter and by the red filter. Directly under these values are the values of I_m, I_y, and I_r, reduced to what their values would have been if obtained at the mean distance of the earth from the sun. At this season of the year the earth is very near its point of minimum distance from the sun. Finally, under I_m a third value represents the intensity of the radiation in the entire solar spectrum, after reduction to mean solar distance

and division by Abbot's mean value of the solar constant, 1.94, expressed as a percentage.

The values I_y and I_r have next to be corrected for the absorption by the glass filters, including the effect of temperature on the absorption, and the reflection from the surfaces of the quartz plate, in addition to the small absorption by quartz in a narrow band in the infrared (table 3). As shown, the reflection is close to 9 percent.

TABLE 2.—*Thermopile reductions, atmospheric turbidity, and water vapor content*

[Blue Hill Meteorological Observatory of Harvard University, lat. 42.2°; long., 71.1°; altitude, 670 feet]

(1) Date and hour angle	(2) Solar altitude	(3) Air-mass	(4) I_m	(5) I_y	(6) I_r	(7) $\dfrac{I_y}{0.851+c}$	(8) $\dfrac{I_r}{0.840+c}$	(9) (4)−(8)	(10) (7)−(8)	(11) $\dfrac{\beta}{(9)}$	(12) $\dfrac{\beta}{(10)}$	(13) Mean of (11) and (12)	(14) $\dfrac{I_{w-o}}{1.94}$	(15) $\dfrac{I_{w-o}-I_m}{1.94}$	(16) w	(17) Air-mass type
	° ′	m	*gr. cal.*	*gr. cal.*	*gr. cal.*										*mm.*	
1935, Dec. 28																
2:35 a. m_____	20 29	2. 24	{ 1.227 1.187 61.2	{ 0.895 .865 ---	{ 0.757 .732 ---	1.000	0.864	0.323	0.145	0.055	0.074	0.064	63.9	2.7	1.4	P_A
0:51 a. m_____	23 24	2. 51	{ 1.383 1.337 68.9	{ .973 .941 ---	{ .805 .778 ---	1.098	.919	.418	.179	.028	.028	.028	75.5	6.6	4.2	
0:38 p. m_____	23 53	2. 46	{ 1.378 1.333 68.7	{ .956 .925 ---	{ .805 .778 ---	1.079	.919	.424	.160	.032	.032	.032	74.4	5.7	3.5	
2:08 p. m_____	18 06	3. 16	{ 1.252 1.211 62.4	{ .915 .885 ---	{ .739 .715 ---	1.033	.844	.367	.189	.026	.026	.026	70.8	8.4	4.6	P_A

Dec. 28, 1935: Time correction for longitude, −15 minutes, 32 seconds; for equation of time, +1 minute, 25 seconds. Total correction, 75th meridian to apparent time, −14 minutes 7 seconds.

TABLE 3.—*Reflection and transmission of radiation through a quartz tube 29.915 millimeters long*

Wave length	Reflection	Wave length	Trans-mission	Transmission through thin plates computed by H. H. Kimball, from foregoing. Transmission for plate	
				1 millimeter thick	0.5 milli-meter thick
μ	*Percent*	μ			
0. 325	0. 9062	----------	----------	----------	----------
.340	.9069	----------	----------	----------	----------
.358	.9077	----------	----------	----------	----------
.361	.9078	----------	----------	----------	----------
.396	.9091	----------	----------	----------	----------
.405	.9094	----------	----------	----------	----------
.410	.9095	----------	----------	----------	----------
.434	.9101	----------	----------	----------	----------
.486	.9113	----------	----------	----------	----------
.508	.9115	----------	----------	----------	----------
.5349	.9119	----------	----------	----------	----------
.5893	.9125	0. 5893	0. 9958	----------	----------
.6158	.9127	----------	----------	----------	----------
.643	.9129	----------	----------	----------	----------
.6563	.9130	----------	----------	----------	----------
.6678	.9130	----------	----------	----------	----------
.6768	.9131	----------	----------	----------	----------
.686	.9133	----------	----------	----------	----------
.7065	.9134	----------	----------	----------	----------
.7435	.9136	----------	----------	----------	----------
.760	.9137	----------	----------	----------	----------
.7682	.9138	----------	----------	----------	----------
.8007	.9139	----------	----------	----------	----------
.8325	.9141	----------	----------	----------	----------
.8671	.9142	.8820	.9955	----------	----------
.9325	.9145	----------	----------	----------	----------
1.0715	.9145	----------	----------	----------	----------
1.2215	.9154	----------	----------	----------	----------
1.376	.9159	----------	----------	----------	----------
1.670	.9169	1. 6132	1. 0000	1. 000000	1. 000000
1.870	.9176	1. 7835	.9999	.999999	.999999
1.999	.9181	1. 9518	.9976	.999992	.999962
2.170	.9188	2. 1128	.9948	.999838	.999914
2.384	.9198	2. 2654	.9880	.999508	.999809
2.574	.9207	2. 4093	.9795	.999310	.999655
2.746	.9218	2. 5458	.9555	.998488	.999242
2.904	.9226	2. 6120	.9399	.997936	.998852
3.058	.9235	2. 6757	.9272	.997484	.998741
----------	----------	2. 7392	.8446	.994386	.997189
----------	----------	2. 8010	.5789	.981946	.990031
----------	----------	2. 9213	.0814	.919782	.959055
----------	----------	3. 0373	.1549	.939727	.969395

See Coblentz, W. W. Absorption, Reflection, and Dispersion Constants of Quartz. Bull., U. S. Bureau of Standards, vol. 11, no. 3, pp. 471–481; May 10, 1915.

The absorption, while apparently inconsequential, could not be disregarded, for the reason that it all occurs in a band between 2.00μ and 3.00μ, where, according to Feussner (5), the intensity in the red screen is decreasing faster than in the yellow screen.

Feussner has given (5) the spectral transmission of the yellow (OG1) and red (RG2) Schott glass filters, for wave lengths between 0.511μ and 2.860μ. From table 111, column 6, Smithsonian Meteorological Tables, Fifth Revised Edition, may be obtained the computed intensity of solar radiation that would be observed at the surface of the earth at sea level in an atmosphere free from dust and water vapor, with the sun in the zenith. By a few interpolations, these intensities may be tabulated from w at 5′ deviation intervals over the range of wave lengths covered by the transmission of the Schott glass filters. With slight interpolations, the transmissions may be tabulated for the same wave lengths as the intensities. There remains only a small amount (less than 3 percent of the total) for which the distribution of intensity must be estimated, but for which the transmissions in the infra-red are available as an aid.

Evidently, the sum of the products of intensities by transmissions, divided by the sums of the intensities, gives for each screen the average transmission for that part of the spectrum it transmits. In this way it has been determined that the transmission of the yellow filter (OG1) is 0.851, and that of the red filter (RG2) is 0.840; these values have been determined when the temperatures of the screens were between 20° and 25° C.

As to the change in transmission of these screens with temperature, Gibson (6) found that for a decrease in temperature from +20° C. to −80° C., a decrease of 100° C., the increase in transmission for the yellow screen is 1.96 percent, or 0.2 percent per 10° decrease. With a temperature increase from +20° C. to +100°, an increase of 80° C., the decrease in transmission for the yellow screen is 2.85 percent, or 0.356 percent per 10° increase. For red screen (RG2), a decrease in temperature from +20° C. to −80° C. or 100° C., causes a percentage increase in transmission of 2.44, or 0.244 percent per 10° C.; and for an increase in temperature from +20° C. to +100° C., or 80° C., the decrease in transmission is 2.185 percent, or 0.273 percent for 10°.

We thus obtain the following tables of transmissions to be used in determining the radiation intensity in the

spectral bands that are transmitted by Schott glass filters OG1 (yellow) and RG2 (red):

TABLE 4.—*Transmission coefficients for different temperatures of screens*

Temperature		Transmission	
° F.	° C.	OG1	RG2
−36	−38	0. 863	0. 855
−18	−28	.861	.852
±0	−18	.859	.850
+18	−8	.857	.847
+36	+2. 2	.855	.845
+54	+12. 2	.853	.842
+72	+22. 2	.851	.840
+90	+32. 2	.847	.837
+108	+42. 2	.844	.835

Baker (8) has made extensive measurements of the temperature of the Schott glass color filters when exposed to sunlight, as they are for 3 minutes while measuring the intensities I_y and I_r. His measurements, summarized in table 1 of the next paper in this REVIEW, indicate that the color screens have at the beginning of exposure a temperature 1.2° C. above air temperature, and that the average excess during the 3 minutes exposure is 1.4° C.; thus, there is an average total excess of 2.6° C. above air temperature. This is indicated in table 2, in the headings of columns (7) and (8), by writing in the denominator of each fraction, after the number that denotes the value of the transmission at temperature 22.2° C., the letter c., to indicate that a correction is to be applied to make the denominator agree with the value given in table 4 at the temperature of the screens.

Returning now to table 2, we find that the divisors throughout December 28 were 0.857 for the yellow screen and 0.847 for the red, appropriate to a midday temperature of about +17° F., or −9.3° C. for the air, and about −6.7° C. for the glass screens.

From this point on, the work in table 2 is simple: Each set of values of I_y and I_r is divided by its transmission coefficient, determined in the same manner as in the example just given. The value of I_r thus obtained is then subtracted successively from I_m and I_y; and from the results, by interpolation in figures 3 and 4, this REVIEW, March 1933, page 64, we obtain the value of β, the coefficient of atmospheric turbidity for the time at which the solar radiation measurements were made. Two deter-minations of β are obtained, one from the value of $I_m - I_r$ and the other from the value of $I_y - I_r$, representing intensities in different parts of the solar spectrum. (See above reference, figs. 3 and 4, for spectral limits in each determination.) It will be noted that the first pair of values were not in so close accord as those obtained later in the day; figure 1 shows that the intensity trace at the earlier time was not so steady as it was later, indicating possible momentary disturbances from local smoke, or, more probably, from thin clouds. During the remainder of the day, sky conditions were remarkably steady.

Using the mean values of β for each set of measure-ments, we obtain from figure 2, this REVIEW, March 1933, above quoted, the values for I_m in an atmosphere having the turbidity computed for December 28, expressed as a percentage of the solar constant, 1.94. Subtracting from this the value of I_m in table 2, column (4), expressed in the same units, we obtain the percentage loss that may be attributed to absorption by gases in the atmosphere. Deducting 0.3 from the total loss by absorption given in column (15), and dividing the remainder by $\sqrt{m}$, we obtain what appears to be a close approximation to the depth of water that would be formed if all the water vapor above the place of observation were precipitated.

The small amount of water vapor indicated by the morning observation is probably due to an overestimate of the loss by scattering; or in other words a too high value of β led to a too low value for w.

Under "Air mass type", in the last column of table 2, is given the probable source of origin of the air as indicated on air mass analysis maps.

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MEASUREMENT OF SCHOTT GLASS FILTER TEMPERATURES

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In the solar radiation program at Blue Hill Meteoro-logical Observatory, atmospheric turbidity and water vapor content are measured by a method developed by H. H. Kimball. In this method the energy in selected regions of the spectrum, received at normal incidence, is measured by means of a thermopile. Isolation of the desired spectral regions is effected by two Schott glass filters, mounted in such a way that they can be swung in and out of the incident beam in succession.

It is a well-recognized fact that the transmission of radiation through any filter that exhibits either selective or nonselective absorption is a function of temperature. The purpose of the present investigation was to measure the temperatures which the filters assumed, in order that a temperature correction to the transmission might be applied.

The filters are circular in shape, 3 centimeters in diameter, one-half millimeter thick, and are mounted as shown in figure 4 of the preceding paper by H. H. Kim-ball. It is obvious that a determination of the internal temperature of the filters is impracticable. A good approximation to the internal temperature is the surface temperature, which could quite easily be measured. Accordingly the surface temperature of the filters was measured under the actual conditions of use. An instru-ment based on the thermoelectric effect seemed most feasible for the measurement. Thermocouples were constructed and were found quite satisfactory for the purpose.

In use the filter is swung into a position such that its surface is normal to the incident beam. This position is maintained usually for 3 minutes. Two questions